APPROACHES TO DEVELOPING A DECISION SUPPORT SYSTEM FOR MANEUVERING CONSIDERING NAVIGATOR FATIGUE

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Introduction. Ship collisions at sea represent the most dangerous emergency situations, leading not only to economic losses due to damage or total destruction of cargo and vessels but primarily resulting in the loss of human lives and causing irreparable environmental harm. One of the main duties of a navigation officer during watchkeeping is to avoid situations of close-quarter encounters and prevent collisions. To coordinate and regulate ship movements, the International Regulations for Preventing Collisions at Sea (COLREGs-72) [1] were adopted in 1972. The application of these rules enables navigators to make correct decisions to ensure the safe movement of vessels in various waters and to prevent collisions.

Knowledge and the ability to apply the COLREGs-72 are mandatory professional skills for navigation officers. Therefore, special attention is paid to them during training, certification, and employment of specialists. However, despite this emphasis, the accident rate has not decreased in recent years, and one of the reasons is the neglect of the COLREGs. A common violation among both young specialists and experienced officers is the use of VHF communications to negotiate maneuvers instead of following the recommendations outlined in the Rules. From the perspective of good seamanship, such decisions are the most dangerous because they involve numerous negative human factor influences [2], as well as equipment limitations and malfunctions [3]. Given the extensive focus on COLREGs knowledge at all stages of maritime professional development, it seems highly unlikely that officers simply "do not know" the rules.

Analysis of previous research. Fatigue is one of the factors that adversely affect a person's performance, reducing their ability and willingness to utilize acquired knowledge and skills. A fatigued individual tends to make the simplest, quickest, and least energy-consuming decisions, which are not always correct. This predisposition can lead to incorrect decision-making regarding collision avoidance between vessels.

It is known that fatigue manifests most intensely during night watches and towards the end of a watch period. The feeling of fatigue is also influenced by an individual's biological or circadian rhythm, which regulates human biological activity throughout the day.

Main part. Rule No. 2 of the COLREGs-72, "Responsibility," mandates the obligatory use of these rules in all situations, while considering the specific characteristics of vessels and circumstances [4], as well as good seamanship practices. This may involve deviations from the rules when necessary due to special conditions. This rule presents us with two courses of action that can be considered relatively correct if a collision is avoided:

Most Correct: Adhering strictly to the rules.

Less Acceptable but Not Incorrect: Deviating from the rules if the situation requires it.

Additionally, a third option exists: contacting the other vessel to agree on a maneuver. Since the COLREGs do not regulate the use of radiotelephony in this context, and our primary goal is to prevent accidents by any means, this option cannot be deemed incorrect. However, it is considered the least favorable decision.

To test our hypothesis, we constructed individual circadian rhythms for navigators and developed tables illustrating the frequency of action patterns depending on one of the factors (see Fig. 1 and Table 1).

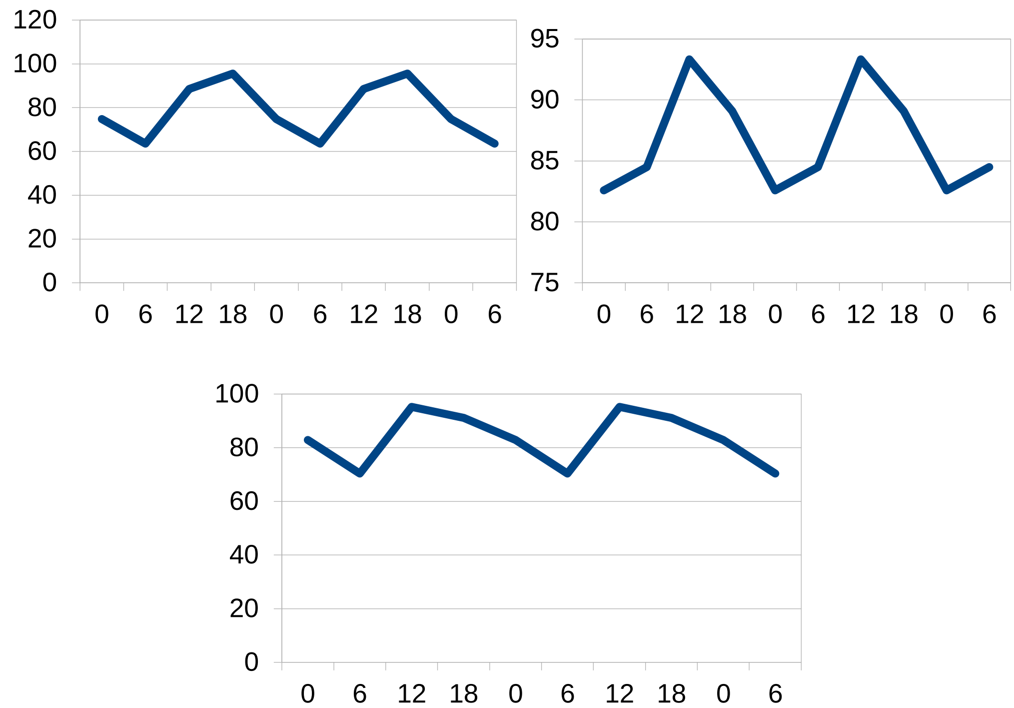

Figure 1. Individual Circadian Rhythm

	Day or night watch		Begin or end of watch		Circadian	
Master	Day	Night	Begin	End	Grow	Fall
Follow COLREG	17	14	26	5	17	14
Step Away COLREG	7	5	3	9	8	4
VHF	4	20	7	17	10	14
	Day or night watch		Begin or end of watch		Circadian	
CH.OFF	Day	Night	Begin	End	Grow	Fall
Follow COLREG	18	15	16	17	19	14
Step Away COLREG	10	8	9	9	6	12
VHF	9	20	12	17	14	15
	Day or night watch		Begin or end of watch		Circadian	
2ND OFF	Day	Night	Begin	End	Grow	Fall
Follow COLREG	12	10	14	8	11	11
Step Away COLREG	5	9	6	8	7	7
VHF	1	14	5	10	6	9

Table 1 – Frequency of Action Patterns Depending on Influencing Factors

Using this table, we sampled decision patterns considering our three factors, resulting in 18 states for each navigator—6 variants of each action pattern—which we analyzed for Pareto optimality. The general algorithm for finding solutions involves the sequential reduction of the X initial set.

Select the first alternative x_1 from the set X and form a new set X_1 from X by comparing x_1 with all other alternatives.

If there exists a decision x such that $x \succ x_1$ (i.e., x_1 dominates x), then x is not included in X_1 (meaning it will obviously not be Pareto-optimal).

If no x is found such that $x \succ x_1$, then x_1 is included in the Pareto set XP and is no longer considered in the next step and, therefore, is not included in X_1.

Repeat these operations by taking the next alternative x_1 and forming the set X_2 from X_1.

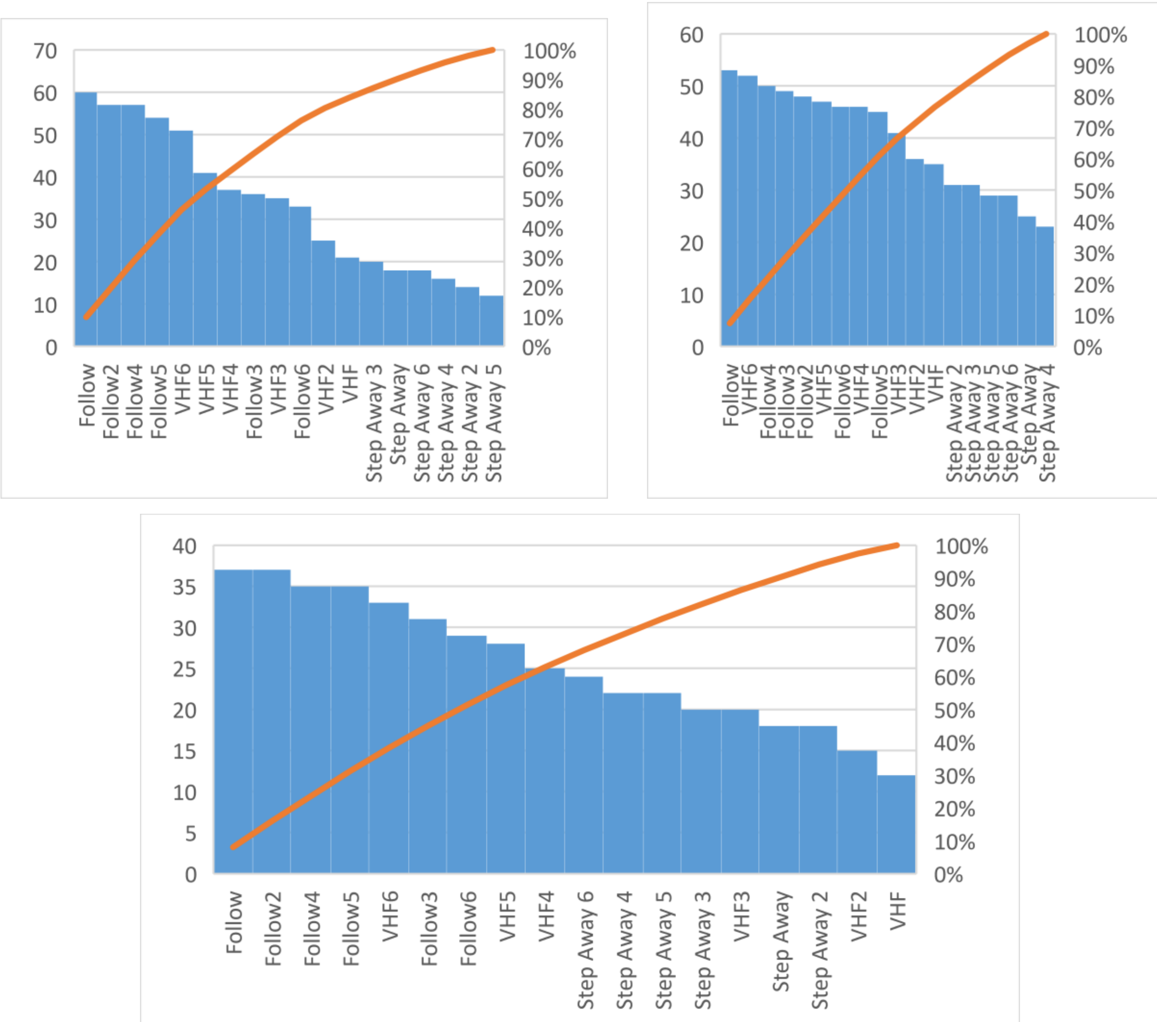

Figure 2 – Pareto Distribution

As we can see from the graphs, the action pattern of using the COLREGs prevails over all others. However, during night hours at the end of the watch, when the circadian rhythm approaches its minimums—i.e., when the feeling of fatigue is greatest—the use of VHF communication to resolve situations increases to 70–90%. Therefore, we can confidently say that fatigue affects the choice of method.

It is known that fatigue suppresses the cognitive functions of the body and reduces motivation [5], which in turn leads to an unwillingness to use intellect, knowledge, and skills. The psyche, transitioning to lower levels of consciousness, employs the simplest and least energy-consuming action patterns. Unfortunately, such patterns usually turn out to be erroneous.

A decision support system (DSS) based on the structured COLREGs-72 convention, capable of suggesting maneuvers and allowing the navigator to analyze the maneuver rather than the overall navigational situation, could reduce the risks associated with using such patterns and, consequently, the risk of ship collisions [6].

Despite some provisions of the Rules having ambiguous interpretations and the ongoing formalization of models, there are only three maneuvers for collision avoidance according to the Rules:

- Changing course (including turning).
- Changing speed.
- Changing both course and speed.

By receiving data from navigation devices and detecting danger based on predefined parameters, the system could calculate the necessary maneuver using the formalized rules of COLREGs Part B and propose it to the officer (Figure 3).

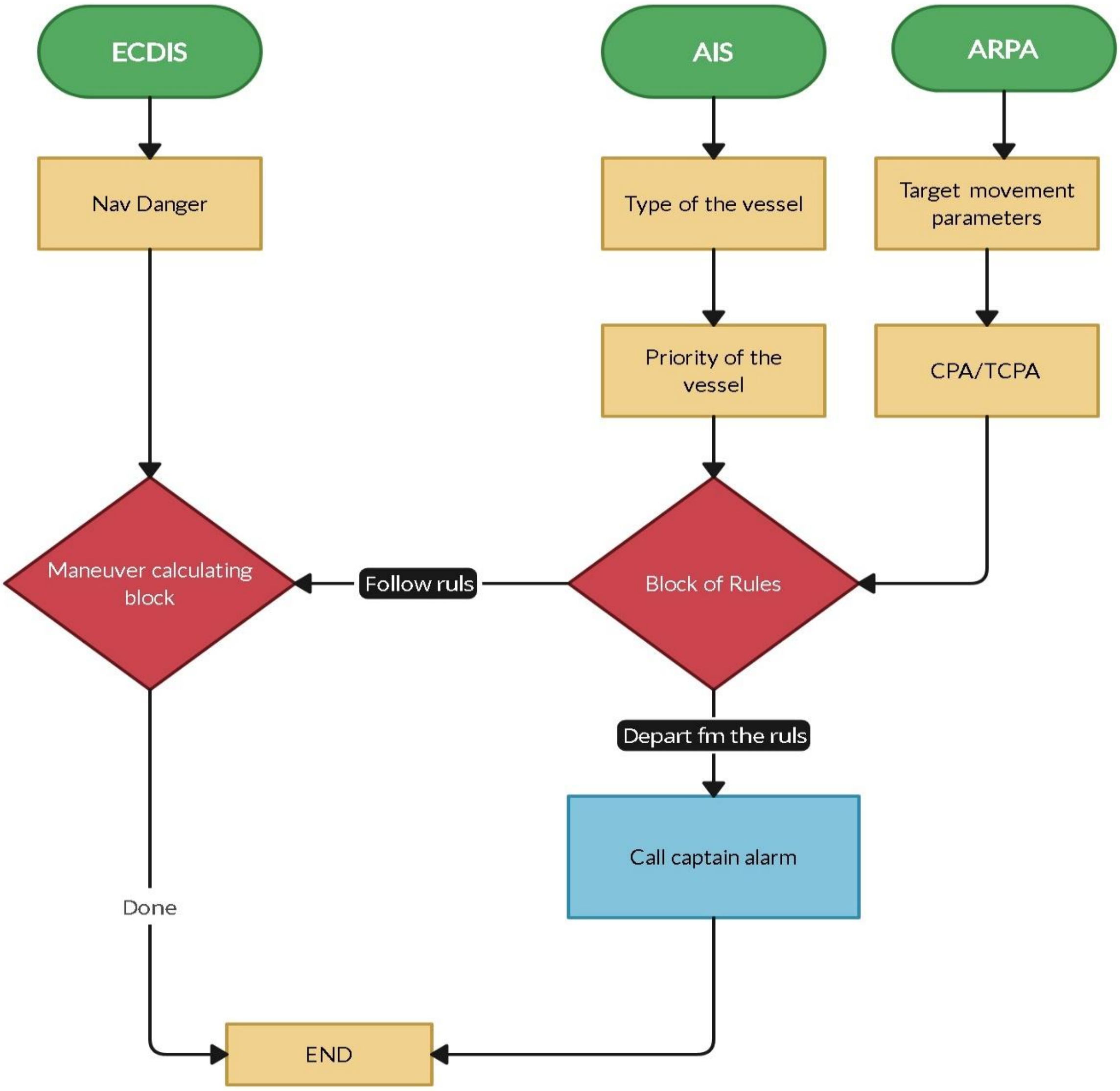

Figure 3 – Principal Block Diagram of the Decision Support System (DSS)

Conclusions. Fatigue is indeed a highly influential negative factor in decision-making to ensure navigational safety. Under its influence, a person's psyche transitions to lower states, causing a reduction in cognitive abilities and leading to the selection of incorrect decisions. A DSS based on the formalized rules of COLREGs-72 Part B would allow the officer, during a complex psychophysiological state, to receive a ready-made maneuver that is correct from the convention's point of view, accelerating actions to prevent collisions and partially mitigating the negative effects of fatigue.

Further studies will be aimed at a more detailed examination of the phenomenon of fatigue to timely and preventively detect its negative impacts. This includes the development of a fatigue monitoring and forecasting system as part of the DSS to ensure the safety of navigation, cargo operations, and other related activities [7,8].

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